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## NATURAL SCIENCE IN SECONDARY SCHOOLS.

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There are two leading views of the object of teaching natural sciences, one of long standing and the other of more recent growth. According to the former, the aim of such teaching is to furnish material knowledge and give the student a certain amount of practical training for making that knowledge effective in business affairs. The later idea is to supply a general intellectual training, so as to fit students to acquire knowledge for themselves. As in practical life ability to acquire is preferable to simple possession, so in intellectual matters the same preference exists, but in a greater degree. Moreover there is so much to be taught, while the time at our disposal is very limited, that a just selection of subject matter is extremely difficult, particularly since scholars of the present age often have not decided what occupation they will follow, and, even when they have made a choice subsequent events frequently change all their plans. Aside from this consideration, moreover, if the only point were to impart to young students a definite amount of useful information committed to memory, it would be better to furnish them at once with books of reference, which are more reliable than memory and which would also cost the state less than the employment of teachers. Besides, the memory is so much exercised in other ways, and other departments of instruction make such heavy demands upon it, that it ought not to be too heavily burdened by an additional amount of scientific study in which an effort is made to learn a variety of things, names, and classifications that only arouse curiosity for the moment and soon deaden intellectual activity. Of course one gets on faster with a child by carrying it, but it is ~~for the child's interest~~ to teach it to run and to swim by itself. In the same way it is better not to give young scholars scientific knowledge ready made, but to teach them the way to it. By imparting to them results obtained by others the ideal purpose of instruction is seriously prejudiced, the sense of scientifically accurate thinking is destroyed, the belief in authority is increased instead of checked, and the mind becomes surfeited instead of finding pleasure in the exercise of its powers.

This partly explains why high school teachers often prefer those of their scholars who have received no scientific education to those who have received an ill taught smattering of it. But the success of systematic scientific studies in high schools would be much greater, and above all much more certain, if the students had been previously well and methodically taught in the preliminaries in intermediate schools. If such a strict, methodical mental training is omitted in the intermediate schools its loss can hardly be supplied in the high schools.

A certain amount of fundamental knowledge is of course necessary to the student, but this is gradually gained by practical exercise in elementary work in natural history, using meanwhile as material for instruction in such study familiar objects and the more noticeable phenomena of daily occurrence instead of rarities and curiosities. Such knowledge is also more firmly fixed in the mind by observation than by memorizing alone. Natural science is an experimental science, and the beginner must follow the path marked out by it in order to reach the same end. This he must do not by laboriously committing to memory the material of his knowledge as recorded in books, but by learning it through his own observation. It should not be

✓acquired in a systematic but in a methodical way.<sup>1</sup> Teachers, and particularly those who are beginners in their profession, often make the mistake of trying to teach their scholars the advanced knowledge of their own college studies, and of supposing that fifteen year old boys are able to digest matter in a concentrated form which they themselves could only master at the university after numerous demonstrations. They forget that young pupils have not sufficiently developed ideas for such instruction, and that consequently they ought not to proceed with them from the general to the particular, that is to say, according to the analytical method, but should first establish a foundation of individual observations which can finally be united synthetically into a general idea.

Starting from these general considerations the following method of science teaching is proposed :

In such instruction the first thing necessary is practice in observing and in the use of all the senses for that purpose. Gymnasts, painters, and musicians teach us that constant practice alone brings the muscles to obey perfectly the commands of the will, and the same is true of the senses. Not every one who can see sees carefully and accurately. And herein lies the superiority of the trained observer, that he has learned to notice the numerous forms and appearances of things so that he at once sees in them a great deal which others do not see at all.

This constant exercise in carefully observing objects of study should of course be progressive from the easy and simple to the difficult. At first individual things are to be studied by themselves, care being taken not to select objects from too limited a circle; not to confine the attention to mammals for instance while studying the animal kingdom, but to take examples from all classes and divisions of nature. Afterwards comes a comparison of these things previously studied separately, so as to bring out their resemblances and differences. This leads finally to a bringing together of all the things observed, the pupils being confined to their own observations and making from them a general summary, or what may be called a system. In the higher grades of secondary schools it is indispensable to point out that the principal systematic ideas (such as species, genus, &c.) are always obtained by this summing up into one idea of scattered facts of observation.

Since plants offer the most abundant material for study and also early attract the attention of children, it is well to begin the course of instruction with them and proceed to the study of animals later. The examination and determination of minerals are subjects much more difficult to learn. Although the forms of minerals are much simpler than those of plants or animals, yet the beginner will find it much more difficult to tell the normal from the accidental in them than in other cases, as well as to be able to detect the regular or normal forms of one and the same mineral when disguised by accidental causes. Moreover, before mineralogy can be successfully taught, students must have some knowledge of physics, chemistry, and stereometry. However, every scholar should be induced to notice how various kinds of minerals and rocks present themselves in mass in his own neighborhood, and learn to know them. By what they will have learned so far of natural science young students will have reached as a material result of their studies a development of the sense of form, an enlargement of their knowledge of material things and of their ideas about them, and the perception that the earth is a whole made up of interdependent individual parts.

In the next higher grade, training in observation should be directed towards mak-

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<sup>1</sup> By systematic instruction the author means teaching the general principles or "laws" which are the results of generalizing from individual observations, without showing how these general principles were reached. These "laws" or principles when classified and arranged form systems. By methodical instruction, on the other hand, he means teaching the mode of reaching these general principles, viz, by bringing together into one general idea a sufficient number of isolated observations. This is the inductive method, and he insists upon first instructing science scholars in this way before permitting the use of the reverse operation, viz, deduction from the "laws" so obtained to individual cases. This deductive method he also calls analytical.

ing comparisons of the different stages of development of the same organism, that is to say, the pupils should commence the study of natural history. At the same time, in studying the changes which bodies experience under the influence of such forces as do not affect their nature or substance, the domain of physics is reached. Subsequently, because more difficult for beginners, comes instruction in observing the mutual changes of their substance which bodies exert upon each other by which their nature is radically altered, and here begins the study of chemistry. By thus leading the pupil in an orderly manner to observe the various changes to which bodies are subject, an idea is obtained of the real meaning of the word "nature" (from *nasci*, to be born) as expressing something which is constantly and forever springing into being and constantly changing into new forms, so that the scholar learns to think of nature as a whole moved and quickened by internal forces.

Hand in hand with observation goes discipline in describing the things observed. One single observation accurately made is of more value than a thousand anecdotes and illustrations, with which many teachers believe they ought to enliven their instruction. It is not the teacher, however, but the scholar who ought to make the description of the things under observation, that is, the things he has himself observed, not the things with which he has burdened his memory without observation. Accurate description (with drawings, if possible) serves as a check upon the inaccuracy of the observations, and besides gives students a correct comprehension of words with which they are already familiar, or by leading them to look up new terms enriches their vocabulary and develops a versatility in the use of language, particularly if the teacher is strict in limiting them to the use of general terms. Practice in giving definitions should be undertaken at the same time. This kind of scientific teaching would be a capital aid to instruction in the mother tongue, and in a way for which there is no substitute; for here there is a kind of direct translation out of nature into one's own speech. In fact there are in this case neither words nor forms of sentences to start with, and the authority and help of dictionaries are wanting, so that the student has to rely upon himself and must acquire a good degree of independence in giving his ideas. The objection that the same end could be reached by the ordinary instruction in the mother tongue as an accompaniment to natural science teaching is not a sound one, because the teacher of languages is unfortunately too often destitute of the necessary material knowledge, and is often also ignorant of the methodical way of schooling the mind which should be followed in teaching the natural sciences. Of course this practice in giving clear descriptions would follow the progress of the subject matter taught—from the easy to the difficult—and the selection of material for this reason also ought to be varied as much as possible. After scholars have learned to understand the accurate significance of words by the method above sketched out they will be better qualified to convey their own ideas in a simple and clear way to others, and also understand more fully the meaning of what is said to them, a faculty of the greatest importance in practical life as well as an essential requisite of education in general.

Instruction in natural science should also be a training in thinking. Pupils should be led to form general ideas or laws from the objects of study and the phenomena presented to them, to draw conclusions upon the causes of such phenomena, and predict the future action of the causes they have learned to know. In this way not only a knowledge but also an understanding of nature is reached. If the young student is led to reflect upon the meaning of the most commonplace natural phenomena, to investigate them himself and compare them together (as, for instance, the form, color, and smell of flowers, the color, coverings, and structure of fruits and seeds, the form and color of the organs of animals, &c.), he will find that while advancing in knowledge the tediousness of having to learn is done away with and pleasure takes its place. As the material result of this side of teaching natural science, the conviction will spring up in the mind of the pupil that all phenomena are governed by fixed, eternal, and unchangeable laws.

To what has been said should be added a few words about teachers, school books, methods and means of teaching, inspectors, and natural history collections, &c.

The teacher of natural science ought to have the necessary special scientific schooling for that purpose. In no department of instruction is it less permissible to teach authoritatively than in this, and to make it a subordinate branch for a teacher not specially prepared for it is often worse than to provide no scientific instruction whatever; for the teacher must not only be master of the material he teaches, but ought also to be a model of the intellectual training he tries to impart; he should have the capacity to observe, describe, and reason accurately about the material of study. In order to give his instruction in such a way as to incite his pupils to an interested activity in their studies, it is indispensable for him constantly to try to develop his own intellectual powers further, and continually refresh them by special studies (which, however, should not be introduced into the school). Not only should every lesson be well prepared, but after every lesson the teacher should give himself an account of the result of his instruction, and, in case of ill success, he should ascribe its cause to himself rather than to his pupils, so as to avoid mistakes in future. One of the commonest faults of teachers is that in order to get on with their pupils as fast as possible they themselves describe the objects or phenomena under consideration and derive laws from them, instead of allowing the scholars to do so. They predigest, in other words, to a certain extent, the intellectual food which they ought to allow the scholars to attack for themselves, subject to control and correction only. A science teacher should be able to show his pupils how to give graphic reproductions of what they have learned. Whatever drawing might be necessary for this purpose should not however be presented ready made to scholars, but should be drawn by the teacher on the large scale on the slate or board before their eyes. If the teacher, besides his instruction proper, has to furnish the material for study (e. g., plants, &c.), prepare demonstrations, lead excursions into the field, and have charge of the natural history collections of the scholars, it is clear that a great burden is laid upon him, which is all the greater because natural science teaching is by itself more fatiguing than other branches, since it requires the guidance of each individual scholar, and because the attention of the teacher must be divided between the different scholars, the material for demonstration, and the progress of the instruction.

The natural science school book should be used only as a book of reference in reviewing, as a means of saving writing, for recalling to memory the things observed in the course of study, as a help in looking up modes of expression, and particularly as a general model. It should remain closed while teaching is going on. It ought, above all, to be in every respect up to the times in its subject matter, and while being as brief as possible it should afford an accurate and complete selection of topics. It would be a great mistake if the school book were made a transcript of the course of teaching. It ought therefore to have a systematic and not a methodical arrangement, so that at the end of the course it would serve as a general summary of the observations and inductions made by the scholars. It is indispensable for scholars to prepare their own descriptions and drawings and work up their notes in the form of small treatises or dissertations notwithstanding a simultaneous use of the school book.

Methods of instruction are generally faulty in aiming at a practical training for some business career at a stage where a general training of the mind is the first essential, and in attributing too much weight to systematic instruction. The proper plan of instruction is to make at the outset demands which all the scholars can meet, and not to lead a few qualified scholars to a higher mark. The real master is the one who restricts the scope of the labors of his pupils but is able to bring them all to the limit he has set. By placing his requirements upon them too high he anticipates the aim of the higher schools, and the indigestibility of the material dulls the minds of his pupils and disturbs the quiet development of their thinking powers, or a too early maturity makes them indifferent to further effort.

In this department of instruction no repeating from memory things not observed

by the students themselves and no mere reproduction of school book information should be asked for either in the examinations or by inspectors. Stereotyped questions and answers give no satisfaction, but the aim should be to have the scholars give answers to the questions asked them in their own language, and not that of their teachers or school books. The inspector should look not so much at the variety of information the scholars possess as at their ability and skill in acquiring knowledge. It is not so desirable for scholars to know many things as to thoroughly master and consider from all sides the limited amount of knowledge they have already acquired. Moreover, the inspector should see to it that the phenomena of every day life and the common objects of nature are used as material for practice in observation. Instead of permitting scholars to report upon out-of-the-way things which they have never seen themselves, he should see whether they know how to treat objects, whether known to them or new, which they have actually observed. He will have occasion to notice that very often a scholar who makes an excellent showing where his knowledge has come from memorizing without observation, is unable to recognize an object submitted to him even if he has already described it from the text book. Acting upon the hints above given, inspectors are recommended to notice how text books are used in teaching, how the demonstrations are carried out, whether and in what way the material and verbal errors of the pupils are corrected by the teachers, whether teachers make their pupils speak only in general terms, and finally what sort of dissertations or treatises the scholars have made aside from the text book.

It is clear from the foregoing that every school ought to be provided with a collection of material and apparatus for demonstration. Too much demonstration should not be allowed at one time, but no lesson ought to pass without laying before the scholars the things which they are studying. Every scholar should be furnished with a good lens for studying more closely very small objects. This lens will also prove useful in many ways in after life.

It is advisable to begin instruction in scientific observation with plants, because every scholar can bring with him into school a perfectly good specimen of some of the numerous plants about him. The species to be studied must be carefully selected from the great number at disposal, so as to make a beginning with the simplest and plainest forms, and bring in representatives of all the principal groups of the vegetable kingdom. It would be advantageous in this connection to select specimens of useful and poisonous plants for study, whereby the sentiments of those who demand a practical tendency in scientific teaching would be regarded. Inasmuch as instruction in botany is limited to summer, plenty of fresh material is always at hand. But it is necessary for the school to have a herbarium of the plants and vegetable products of the region, so that at the general review later in the year the scholars can have furnished them whatever details they may have forgotten.

As a rule specimens of animals and minerals cannot be brought into the school room by the scholars, nor can every scholar be provided with a specimen. In such cases one illustration must serve for demonstration for the whole class, and it cannot be too large, too well drawn, and too distinct. Moreover, the school can have a tolerably large collection of the commoner kinds of insects, snails, &c., kept in small glass cases that can be distributed to the scholars during the recitation. Of such animals, plants, and apparatus as cannot be provided in their natural condition, the school should have as large and attractive representations as possible. In addition to these natural objects, apparatus, and pictures, some technical, microscopical, and anatomical preparations should be added, and, if possible, an aquarium, some house plants, &c. This collection need not be large and cumbersome, for a small but good selection of as striking and consequently of as interesting specimens as possible, preferably of our most ordinary domestic species, will be of the most service and least cost. Such a collection should only contain representations for illustrating the principal systematic groups, the colors and forms of animals at different stages of life and seasons of the year, and for showing the relation between form, color, and abode of ani-

mals. A few exotics would serve to show the differences between organisms of other lands and of our own. The collection may also contain specimens of plants and animals of technical importance, animal and vegetable products, the important parts of animals and plants (such as fruits, skeletons, skulls), animal dwellings, &c. Articles sent to schools by private individuals in order that posterity may read the names of the donors on the labels generally serve no useful purpose and take up valuable space.

It would be a good plan for the proper authorities of the canton to make lists of the articles needed at each school, make it obligatory to supply them, and inform the teachers where they can obtain them of good quality and at the least cost. If purchases were made in common the collections could be obtained at a much less cost. The expense should not deter the boards from making such purchases, for these means of teaching are just as important to schools as the other appurtenances, such as the school-houses, the benches, &c. At any rate the teachers themselves, with the aid of their scholars, friends of the school, hunters, foresters, farmers, &c., can add to the collection many instructive objects without any expense of money. In this way the complete natural history of every locality can be illustrated. And such a collection will be of scientific value, particularly if it is properly arranged and named with the help, perhaps, of kindly disposed scientific men, and in this case it will aid the scholars in arranging their own collections. For these purposes, and in order that it may be a constant source of instruction, the collection should be always accessible, if not in the school room itself, where it would be exposed to dust and dirt, at any rate in an adjoining room well lighted and provided with neat glass cases for containing the specimens.

Natural history teaching would be greatly facilitated if the scholars were compelled to make small collections of their own—not formal museums, but limited collections of typical specimens of the commonest plants, animals, and minerals of the neighborhood, especially of such objects as have been studied and can be easily prepared by the scholars themselves (this would exclude all stuffed animals). Such collections could, of course, be enlarged by articles brought by relatives or friends who have travelled abroad, or which might even be purchased occasionally for trifling sums. Any one object in such a collection (e. g., a leaf or a specimen of a mineral) can be repeatedly figured by the scholars from different points of view, and so give occasion for the habit of a thorough, many sided study of even a common thing. At the same time these collections give practice in determining (classifying) and arranging specimens. They afford recreation to the whole body, and particularly to the eye, which has to accommodate itself to distance while collecting in the open air, and so finds relief from the close attention of the school room. So, also, if scholars prepare the boxes and cases for preserving their specimens, they acquire dexterity and adroitness. This kind of work, which requires much time, may be put off until vacation in order not to interfere with other branches of study. The school will aid the plan of having scholars make natural history collections by planning little excursions, placing utensils and apparatus for making the collections at the disposal of the scholars, and permitting them to determine and arrange their collections in the school museum with the help and under the control of the teachers. The latter must take care that making collections does not become a rage with the pupils, and all tendency to cruelty must be checked.

Objections to this practice of making collections, on the ground that it requires too much time, money, and labor, and turns scholars away from other branches of study, are unfounded. The recreation it affords renders scholars all the more willing to turn to other studies with fresh invigoration. Parents also who at first look askance at this mode of study soon become favorably disposed to it as soon as they find out how decidedly it sharpens the perceptions of their children, develops their capabilities, increases their enjoyment of life and of nature, and also has a healthy moral effect in taking them away from fatiguing parades and other more hurtful pastimes. Every

teacher who understands how to direct the activity of his scholars in this respect into good paths will earn the thanks of their parents and their own in later years.

For the purpose of illustrating the manner of collecting pointed out in the discourse a model of a collection made by scholars of different schools was shown the assembly. Every school should have such a model. It consisted of—

(1) A morphological herbarium and a collection of fruits and seeds made by a scholar of the first class of the canton school in Aarau.

(2) A small zoölogical collection of a scholar of the second class of the canton school in Aarau.

(3) A collection of models of crystals in gypsum made by a scholar of the third class of the canton school in Aarau.

(4) A mineralogical collection made by a third class of the canton school in Aarau.

(5) A small local geognostic collection made by the scholars of a fourth class of the canton school in Aarau.

(6) Models of a mineralogical, rock, and geognostic collection for a secondary school, which with some modifications might be collected by scholars of the third and fourth classes.

All the collections are of such a character that they can be of excellent service to the school in natural history studies. Nos. 2, 4, 5, and 6 are in suitable chests made by the scholars, and every collection is in a specially constructed box so that it can be packed up and shipped with safety.

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